Economic Functioning and Politically-Pragmatic Justification of Tradable Green Certificates in Poland

Christoph Heinzel[†,‡,*] and Thomas Winkler[⋆]

[†] Toulouse School of Economics (LERNA), 21 Allée de Brienne, 31000 Toulouse, France
[‡] Centre for Energy and Environmental Markets, Australian School of Business, University of New South Wales, UNSW Sydney NSW 2052, Australia
[⋆] WSB Neue Energien GmbH, Schweizer Strasse 3a, 01069 Dresden, Germany

Abstract: Quota obligation schemes based on tradable green certificates (TGC) have become a popular policy instrument to expand power generation from renewable energy sources. We analyze the scheme recently introduced in Poland with regard to its economic functioning, and its justification with reference to overcoming typical barriers for renewable-technology deployment. Overcoming such barriers may justify the application of a TGC scheme, beyond a first- or second-best reasoning, on politically pragmatic grounds. High quota requirements make the TGC price track its buy-out level. With high investment incentives, especially for wind power, the scheme helps to alleviate deployment barriers related to infrastructure, funding, and technology availability. However, the scheme is not necessary to overcome barriers on the legal or institutional level. Social acceptance may rather decrease when, after their liberalization, power prices for consumers start to rise.

Keywords: Tradable green certificates, Poland, Environmental policy, Renewable energy sources, Barriers

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[*] Correspondence: Christoph Heinzel, 21 Allée de Brienne, 31000 Toulouse, France, ch.heinzel[at]gmail.com

1 Introduction

Quota obligation schemes based on tradable green certificates (TGC) constitute, along with feed-in tariffs for green electricity, one of the major policies to promote the deployment of renewable generation technologies. Such policies are today applied in a majority of OECD countries (*e.g.*, Australian Government 2009, EU Commission 2008, Wiser *et al.* 2007). An EU member since 2004, Poland generated in 2006 60.8% of its electricity from hard coal, 34.9% from brown coal, 1.7% from natural gas and 2.6% from renewable energy sources (RES) (URE 2007a).[1] In October 2005, Poland introduced a TGC scheme. The scheme shall enable the country to comply with the indicative target of a 7.5% RES contribution to gross electricity consumption by 2010 agreed upon in its EU accession treaty (European Parliament 2003). The target translates into a 10.4% RES quota of total electricity generation for that year. At the same time, Poland has been part of the EU emissions trading scheme since its start in 2005.

Despite the obvious potential importance of support policies of the deployment of RES technologies for a country on the economic level and for its environmental and energy policies, their justification has, interestingly, hardly been discussed in the scientific literature. This discussion seems particularly relevant when a country with little previous experience of RES technologies, such as Poland, commits to such a policy. However, the Polish TGC scheme has not received much attention in the scientific literature yet.[2] We analyze the Polish TGC scheme with regard to its economic functioning, and its justification with reference to overcoming typical barriers for renewable-technology deployment. Such barriers may arise, for example, on legal, institutional, technological and social levels or pertain to infrastructure and funding. Overcoming these barriers may justify the application of a TGC scheme, beyond a first- or second-best reasoning, on politically pragmatic grounds.

From an environmental-economics perspective, the justification of RES support policies is not immediate, if an emissions trading system (ETS) that fully covers the energy industry is in place. According to basic welfare economics, every policy intervention (unless directly enhancing social welfare) needs a market failure as its basis; and every market failure requires, in general, one policy instrument which should mitigate the distortion in question without increasing another distortion (Ng 2004, Stiglitz 2000). The

[1] Of its 4.3 terawatt hours (TWh) of green electricity in 2006 47.4% were generated from hydropower, 43% from biomass, 5.9% from wind, and 3.7% from biogas (GUS 2007).

[2] A few (rather early or survey) papers or studies have covered aspects of RES policies in the region, *e.g.*, Barbu (2007), Hindsberger *et al.* (2003), Paska *et al.* (2009), Podrygala (2008), OPTRES (2007) and Reiche (2006).

release of greenhouse gases (GHG) into the atmosphere, for example, constitutes a market failure because many are likely to suffer from the consequences of climate change, while, without regulation, emitters lack an economic incentive to reduce emissions. In an idealized world, with perfect information, perfect competition and no market failure other than the emissions externality, a cap-and-trade system for GHG emission permits or a GHG emission tax provides a first-best response of environmental policy allowing full internalization of the externality.

If a first-best instrument, in this sense, is unavailable, second-best instruments may be used to mitigate the distortionary effect of a market failure.[3] Feed-in tariffs for green electricity and TGC-based quota obligation schemes constitute examples of possible second-best instruments of environmental policy. While not immediately responding to a market failure, expanded RES use will, in the absence of other environmental policy, mitigate GHG emissions by substitution of conventional fossil energy sources. An ETS, however, caps the emissions from the covered sectors *irrespective* of the generation portfolio. In this situation, expanded RES use can hardly further mitigate the related emissions externality. It rather tends to lead to excessive power generation costs, power prices and rents to green-electricity generators.[4] Moreover, a negative distortion of the carbon price alleviates abatement pressure from polluting technologies.

Of course, in the real world the emissions externality is not the only distortion in an economy, and existing ETS are far from perfect. For example, as opposed to the ideal of a unique carbon price that is applied to all GHG emissions, the EU ETS only covers certain industrial sectors. Also, it is open to debate whether the emissions cap, and thus the carbon price, meet their socially desirable levels. It is therefore important to ask which additional role RES support policies should play in the policy mix that is to sustain the transition to a low-emissions economy. One common idea in this regard is that the expansion of RES use can help technology producers to exploit learning-curve effects.[5] In a more dynamic view, inducing expanded RES use in the present may,

[3] Generally, the theoretical justification of policy interventions in a second-best world is subtle (see Cremer *et al.* 1998, Fullerton and Wolverton 2005, and the references therein for a useful discussion). Fullerton and West (2002), *e.g.*, study for car emissions (where, in contrast to the energy industry, a first-best response is actually unavailable) how other policy measures can mimic a direct emissions tax.

[4] See, for example, Böhringer and Rosendahl (2010), Pethig and Wittlich (2009) and Traber and Kemfert (2009) for illustrations of these relationships. Frondel *et al.* (2008) calculate that due to the German feed-in-tariff scheme an average household has additional annual power costs of about €31.5. Subsidies for photovoltaics (PV) alone cumulated to about €26.5bn since the introduction of the scheme in 2000 until 2007, to which by 2010 another €27bn will add. The abatement of 1 tonne CO_2 through additional PV use costs about €760.

[5] As is well recognized, the innovation and diffusion of new technologies may be accompanied by market failures in form of knowledge spillovers as related to the public-good nature of new knowledge from

furthermore, facilitate later tightening of the emissions cap. These further important features, which relate directly to technology production or the political economy of the transition process, are beyond the scope of the present study. We rather focus on the aspect of overcoming barriers for renewable-technology deployment through RES support policies, and consider the available evidence from the recent Polish case.

Apart from numerous studies on regional systems, the literature on TGC schemes has compared their effectiveness and efficiency with those of feed-in tariffs (*e.g.*, Finon 2006, Finon and Menanteau 2004, Finon and Perez 2007, Menanteau *et al.* 2003, Palmer and Butraw 2005).[6] The interaction with an ETS has been analyzed (*e.g.*, Amundsen and Mortensen 2001, Del Rio 2007, Gillenwater 2008b, Jensen and Skytte 2003, Morthorst 2001). Further contributions have focused on particular aspects, such as the relationship between wind supply volatility and TGC price (Lemming 2003), certificate banking and TGC price volatility (Amundsen *et al.* 2006), and the role of long-term contracts for TGC-market efficiency (Kildegaard 2008). None of these contributions treats the justification question as a particular issue. Deployment barriers have also been considered, *e.g.*, by Neuhoff (2005), Neuhoff and Twomey (2008) and Sorrell and Sijm (2003), and in OPTRES (2007) and Sorrell (2003).

The paper proceeds in three steps. Section 2 describes the Polish TGC scheme and its development in the recent past and near future with a focus on its economic functioning. In Sect. 3, we analyze the current conditions for wind-power investments in Poland based on a cash-flow model. The aim is to derive an indication of the effectiveness of the support scheme. (Data for an econometric analysis are not yet available.) We compare the two options of market sale of both green power and TGC and of a bilateral contract between generator and distributor that specifies the prices of both. In Sect. 4, we discuss, in view of the findings of Sects. 2 and 3, how overcoming barriers for RES use supports the application of the Polish TGC scheme. Section 5 concludes.

research and development (R&D), learning by doing or learning by using (Jaffe *et al.* 2002, 2005). Typically, a Pigou subsidy or a respective credit, as first-best measures, can reward an RES technology producer for foregone rents which others appropriate when using the newly generated knowledge in their own production. Whether implicit subsidies for RES technology use constitute an appropriate instrument to internalize these technology-related externalities is, however, not clear (*e.g.*, Garnaut 2008).

[6] See, *e.g.*, Agnolucci (2007) for a survey, and Gillenwater (2008a,b), Wiser *et al.* (2005) for fairly encompassing discussions of definition and different aspects of TGC schemes.

2 The Polish TGC scheme

The Polish TGC scheme, as is characteristic for such schemes, requires electricity distributors to prove that a certain proportion (quota) of their electricity sold is generated from RES.[7] The quota is defined by the Ministry of Economy and amounted to 3.6% in 2006, 5.1% in 2007, and 7% in 2008.[8] Retailers are obliged to grant grid access to RES power generators. The fed-in green electricity is remunerated to producers at the average market price of conventionally generated electricity, the level of which is calculated and announced by the Polish energy regulatory office URE.

Retailers prove quota fulfillment by submitting green certificates to the URE. The URE also issues the so-called certificates of origin which confirm the amount of RES power produced by the green power generator. No distinction is made regarding whether green electricity is generated from hydropower, wind, biomass, biogas, photovoltaics, solar or geothermal energy. The certificates of origin entitle their owners to sell the corresponding amount of RES property rights at the Polish Power Exchange POLPX (POLPX 2010a). RES property rights are denoted in kilowatt hours (kWh). The price of certified green power is indicated at POLPX in Polish Złoty (PLN) per megawatt hour (MWh), hence, per 1,000 RES property rights. For ease of exposition, we will use the term tradable green certificate (TGC) in the following to refer to such a package of 1,000 RES property rights. Note that, strictly, the term TGC is not defined in the Polish system. The certification of green power is of indefinite maturity, so that certificates can be banked across trading periods. They are redeemed by submission to the URE.

Retailers may either buy electricity and green certificates at POLPX, or receive them via bilateral long-term contracts with RES generators in which the two parties fix the prices of both electricity and green certificates. There is no legally defined upper or lower price limit in certificate trading. Decisive for quota fulfillment is the amount of certified green power covered by the submitted certificates, not whether RES electricity has actually been provided to consumers according to the quota. A retailer who fails to fulfill the individual RES quota has to pay a substitute fee for the unfulfilled part. The substitute fee is announced and meted out by the URE. In 2006, it was €61.60 (PLN 240) per missing MWh of certified green electricity, in 2007 €64.06 (PLN 242.40), and in 2008 €70.74 (PLN 248.46) (URE 2007b, 2008a).[9] The level of the substitute fee

[7] See Lemming (2003), Menanteau *et al.* (2003), *e.g.*, for general descriptions of TGC schemes. The legal basis of the Polish TGC scheme is the Energy Law (Sejm 2010).

[8] See Table 1 for the period 2009-2014.

[9] Our calculations have been in PLN, as is the certificate trading. To display, to some extent, the exchange-rate volatility to which actors are subject, we indicate prices in this section in nominal

introduces an upper price limit in the TGC market, the so-called buy-out price. In case of quota nonfulfillment and failure to pay the substitute fee, a fine is due whose level per missing MWh is also determined by the URE.[10]

2.1 Development of TGC prices and RES generation

In 2006, for gross electricity consumption of 150.87 terawatt hours (TWh)[11] (Paska *et al.* 2009), the production of 5.43 TWh of green electricity would have been necessary to meet the RES quota of 3.6%. However, green power generation only reached 4.2 TWh in that year (Ministry of Economy 2008, Paska *et al.* 2009). In 2007 and 2008, gross electricity consumption rose, respectively, to 154.17 and 154.89 TWh (PSE Operator 2009), with corresponding requirements of 7.86 and 10.84 TWh of green electricity to satisfy the RES quotas of, respectively, 5.1 and 7%. To meet the 2007 requirement of electricity from RES, as compared with 2006, an increase of green power generation by 87% would have been necessary, and to comply with the 2008 requirement another increase by 37%. However, green power generation only reached 5.23 TWh in 2007 (URE 2009) and 6.49 TWh in 2008 (URE 2010a), or 66.5 and 59.9% of the quota requirements, respectively. In line with this production gap was the development of the TGC price, which virtually tracked the level of the substitute fee for a missing MWh of certified green electricity of €61.60 (PLN 240) from the second half of 2006 onwards (Fig. 1).

Beside certificate trading at POLPX, it is also possible to sell TGC directly to distributors via bilateral contracts. In 2007, 74.4% of all TGC were traded this way (POLPX 2008). The price for these transactions ranged from €39.64 to 63.43 (PLN 150-240). The remuneration for RES power fed into the grid, which is based on the price of conventionally produced power, amounted to €30.72 (PLN 119.7) in 2006 and to €34.04 (PLN 128.8) in 2007 (URE 2007c, 2008b). In 2007, RES producers could thus have realized a combined revenue from TGC and electricity of up to €97.47 (PLN 368.8) per MWh green electricity generated.

Euro and PLN values. The annual average exchange rate was PLN 3.8959/€ in 2006, PLN 3.7837/€ in 2007, PLN 3.5121/€ in 2008 (ECB 2009).

[10] The fine cannot be lower than 130% of the substitute fee. We thank an anonymous reviewer for this point.

[11] A terawatt hour is 10^6 MWh.

Figure 1: OZEX (TGC-price index at POLPX) (data: POLPX 2008).

2.2 Development forecast for the Polish TGC market

For a judgment of the possible development of the Polish TGC market in the near future, it is first necessary to estimate the required amount of certified green electricity. Table 1 lists the results, derived using the estimates of gross electricity consumption for the years 2009–2014 from the URE (2010a: 69).

Table 1: Estimation of required certified green power 2009–2014.

	2009	**2010**	**2011**	**2012**	**2013**	**2014**
Total power consumption (TWh)	158.1	159.9	162.8	165.7	168.5	171.2
RES quota (%)	8.7	10.4	10.4	10.4	10.9	11.4
Required green power (TWh)	13.57	16.63	16.93	17.23	18.36	19.51

The development of hydropower is restricted by the government to avoid further intrusion into ecological systems by this technology. Therefore, only a slight increase in small hydropower is expected (Paska *et al.* 2009), so that electricity generation from hydropower is unlikely to exceed 2.1 TWh in the near future.

Further available technologies to increase RES power generation in Poland include biomass and biogas. Power generation from these sources reached 1.9 TWh in 2006, 0.5 TWh more than in 2005 (Paska *et al.* 2009). The German Ministry of the Environment estimates a range of €80–210 for the power generation cost of biomass and biogas (BMU 2007). In view of the maximum revenue expectation from electricity generation and TGC for 2007 of about €97.47 per MWh, as calculated above, the TGC scheme itself can be expected to provide only limited investment incentives for biogas and biomass, due to the high risk for such projects to become unprofitable when the TGC price decreases. However, an important fraction of the power generation from biomass is due to cofiring in conventional power plants (*e.g.*, Ministry of Economy 2008). Moreover, for biogas, particular promotion schemes are in place (BSJP and Taylor Wessling 2009a). While cofiring is cheap in the immediate term, its use in conventional plants without causing damage is not unlimited. Overall, the development of biomass and biogas in the near future is difficult to predict. Therefore, we assume that their annual growth will persist at the constant amount of 0.5 TWh until 2014.

Under this assumption and for hydropower production in 2014 of 2.1 TWh, a production gap of 11.51 TWh remains to fulfill the RES quota shown in Table 1. This gap could possibly be filled by electricity from wind power plants. At the beginning of 2011, their capacity amounted to 1.181 MW (PSEW 2011). PSEW (2008) estimates the load factor for wind energy plants in Poland to be in the range of 20–35%. It can be assumed that projects with the highest load factors will be realized first. An average load factor of 30% then implies the need for 4.380 MW of wind power capacity[12] to fulfill the RES quota of 11.4% in 2014. This value implies the need for an annual capacity growth of about 800 MW until 2014. In 2007, only wind power plants with a capacity of 123 MW have been erected, 268 MW in 2008, 181 MW in 2009 (EWEA 2009), and 456 MW in 2010, resulting in a total installed capacity of 1.181 MW at the beginning of 2011 (PSEW 2011). A rapid increase in the annually erected capacity will thus be required to fulfill the targets.

Because the RES quotas set by the Polish government will hardly be achieved, the TGC price is likely to remain high in the short and medium term. Whether the quota will be fulfilled by 2014 depends on further biomass and biogas growth and accelerated wind power plant construction. If the RES quota is not met in 2014, TGC demand will exceed TGC supply. This should lead to a TGC spot market price near the substitute fee of €70.74 (PLN 248.46).

3 Conditions for wind-power investments

The effectiveness of an RES support scheme ultimately depends on the incentives it sets for the investor. In view of the lack of firm-level data that could be used for econometric

[12] This figure derives from 11,510,000 MWh = 4.380 MW * 24 h * 365 days * 0.30 load factor.

analysis, we analyze in this section the profitability of a hypothetical 20-MW wind-farm project with a 20-year economic lifetime.[13] This permits us to evaluate and compare the two investor strategies for which the Polish TGC scheme allows: selling both TGC and electricity at the relevant exchanges (option 1), and the conclusion of bilateral long-term contracts to sell TGC and electricity directly to distributors (option 2). The analysis helps to evaluate the ability of the Polish TGC scheme to foster the increase of RES production capacity.

3.1 Cash-flow model and framework data

A necessary condition for an investor to invest in a single project is that it has a positive internal rate of return (IRR).[14] A sufficient condition is, in general, that it yields a higher return than a comparable investment on financial markets.[15] RES projects are typically realized by companies founded for a specific project only, so that granted loans have to be repaid by the cash flow of the specific project (Böttcher and Blattner 2006, Wiser and Pickle 1998). We determine the IRR of the reference project based on a standard cash-flow model (*e.g.*, Perridon and Steiner 2007). The IRR is calculated based on the dividends paid to shareholders. In Table 2 we indicate how the dividend payments are calculated.

Table 2: Dividend payment calculation.

	Income from sales
+	Interest received
-	Operation&maintenance costs
-	Depreciation
-	Interest paid
-	Corporate tax
=	**Earnings after taxation**

	Earnings after taxation
+	Depreciation
-	Loan redemption
-	Dividend payout for previous period
=	**Cash flow of the period**
+	Cash on hand from previous period
-	Debt service fund
=	**Dividend payment of the period**

The model also accounts for the perspective of lenders, typically banks. Lenders expect a project cash flow sufficient to serve debt service and to handle risks, such as price

[13] We stick to parameter values as typically used in practice. For example, 20 MW installed capacity of the wind farm constitutes a size big enough for delivery of plants by a technology producer and where financing is still available relatively conveniently. A 20-year economic lifetime is the standard value considered for a wind park; after that time operation-and-maintenance costs increase rapidly.

[14] The IRR is the rate of return for which a project's net present value is equal to zero.

[15] In Subsect. 3.4, we compare the hypothetical wind-farm investment with an alternative financial-market investment.

volatility. We consider two instruments that banks typically use to enforce a sufficient cash flow: the debt service fund, and the debt service cover ratio (DSCR). The debt service fund obliges the debtor to hold back a specific amount of cash for bad periods in which cash flow is insufficient for debt service. (The debt service comprises payments for interest and loan redemption of a period.) Dividend payments are only allowed if the debt service fund contains cash. The $DSCR$ gives an indication of the project's capability to serve the debt service of the period. It is calculated as:[16]

$$\text{DSCR} = \frac{\text{operating cash flow} + \text{debt service fund}}{\text{debt service of the period}}$$

$DSCR < 1$ implies that the project lacks the capability to serve debt service. Therefore, banks usually want a project to fulfill $DSCR > 1$. Wind farms are often required to fulfill $DSCR > 1.3$ (Böttcher and Blattner 2006: 104).

In our model, dividend payments are only possible if the debt service fund reaches 50% of the debt service of the following period, a typical value in practice. For the $DSCR$, we use 1.3 as the benchmark to balance debt and equity. In a projection for the whole of its duration, a project has to fulfill this $DSCR$ in every period. If the project fails to meet this requirement, the initial equity ratio of period 0, before the start of plant operation, has to be increased. If the project achieves $DSCR > 1.3$ in every period, the equity ratio has to be decreased until any period reaches $DSCR = 1.3$. This provides for simultaneous integration of investor's and lenders' perspectives in the determination of the equity ratio in the model. We assume the redeemable loans to have a duration of 13 years, that they are free of redemption in the first year of operation, and have a fixed annual coupon of 7.4%.[17] The annual return on deposits is 3%. We adopt the Polish corporate tax rate of 19%.

As to further framework data, we assume an average load factor of 30%.[18] Thus, the 20-MW wind park will have an annual electricity output of 52,560 MWh. The total investment volume for the wind park amounts to €31.094 million,[19] and the operation and maintenance (O&M) costs in the first year of operation amount to €0.9 million.[20]

[16] The operating cash flow is the cash flow directly generated by the operation of the wind farm. It comprises the earnings after taxation and depreciation, but not loan redemption or dividend payments.

[17] Firms are required to save the debt service saved by the freedom from loan redemption in the first year in the debt service fund.

[18] The load factor of 30% is in the upper third of the ranges in the literature (PSEW 2008: 5, Barbu 2007: 300). Usually more favorable sites are developed first.

[19] The price indications in this section are in values of 2008.

[20] Investment volume and first-year O&M costs are based on ZSW (2008). They include a premium of 2.4% for exchange-rate risks, as the plants have to be imported from the Euro zone.

The annual O&M costs increase in years 1–10 by 3.5%, and in years 11–20 by 2%.[21] The wind farm starts to operate on 1 January 2009.

3.2 Option 1: market sale of TGC and electricity

The analysis of the market-sale option splits into two steps. In the *banking case*, we determine the minimum equity quota claimed, if a conservative lender assumes a worst-case scenario concerning the price development to secure his money. In the *base case*, we calculate the IRR of the project using the equity ratio of the banking case and a price development that an investor could realistically assume.

Banking case. Banks want the project to be able to repay its debts even under the conditions of a worst-case scenario. Given the young markets for green electricity and TGC, and that the project company sells both electricity and TGC at exchanges, the expected price variability is particularly high. We assume that the estimated electricity income will not be increased by the regulatory authority URE, but will remain at its 2007 level of €36.67/MWh (PLN 128.8/MWh) (URE 2008b) during the 20-year duration of the forecast. The demand for TGC is likely to exceed supply in Poland in the next years (Subsect. 2.2). This implies expected TGC prices at the upper limit of €68.34 (PLN 240) at least until 2014. We assume that past 2014 the RES quota may be fulfilled, so that banks consider an income of €0 per TGC for a *worst-case* scenario for the period 2015–2028.[22] For comparison, we give in Table 3 also the results for incomes of €59.45 (PLN 80) and €70.84 (PLN 120). (The required equity quota reaches 0% at an assumed income per TGC of €66.06 (PLN 232).) Within the considered bounds for TGC income after 2014, to ensure a $DSCR > 1.3$ for the whole duration, the reference wind farm needs an equity ratio of between 70.1 and 23.2%, or €21.8–7.2 million (PLN 76.5–25.3 million) equity. The IRR amounts to between 0.51 and 10.51%. Note that, thus, even for the assumption of zero income per TGC in 2015–2028, the IRR is positive.

Base case. The base-case scenario uses the specified equity ratio of the banking case to calculate the project IRR under the assumptions of an investor. In this scenario the power income is increased with the inflation rate, as the regulatory authority (the

[21] The increase in O&M costs of 3.5% in the first ten years corresponds to the average inflation rate in Poland in the last years (it may then join the European Currency Union), the 2% increase to the ECB inflation target.

[22] In early 2008, the moment for which the calculations in this section are timed, the Polish support scheme did only extend until 2014. The assumption of a zero TGC price after 2014 reflects the very conservative behavior of banks one of the authors has consistently encountered when involved in project development in Poland.

URE) links the RES-power remuneration determination to the average market price of conventionally generated power. Because of the expectation of increasing prices for fossil fuels, we increase the RES-power remuneration in the base case by 3.5% p.a. for the years 2009–2018 and by 2% p.a. beginning in 2019. The TGC price forecast is more difficult. In concordance with the banking case, we assume that until 2014 the TGC price will remain at its upper limit of €68.34 (PLN 240). Because we do not know when the RES quota will be fulfilled, we decrease the TGC income in the forecast annually by 20% beginning in 2015.[23] Figure 2 illustrates the price development in the base case. Based on these assumptions and under consideration of an banking-case equity ratio of

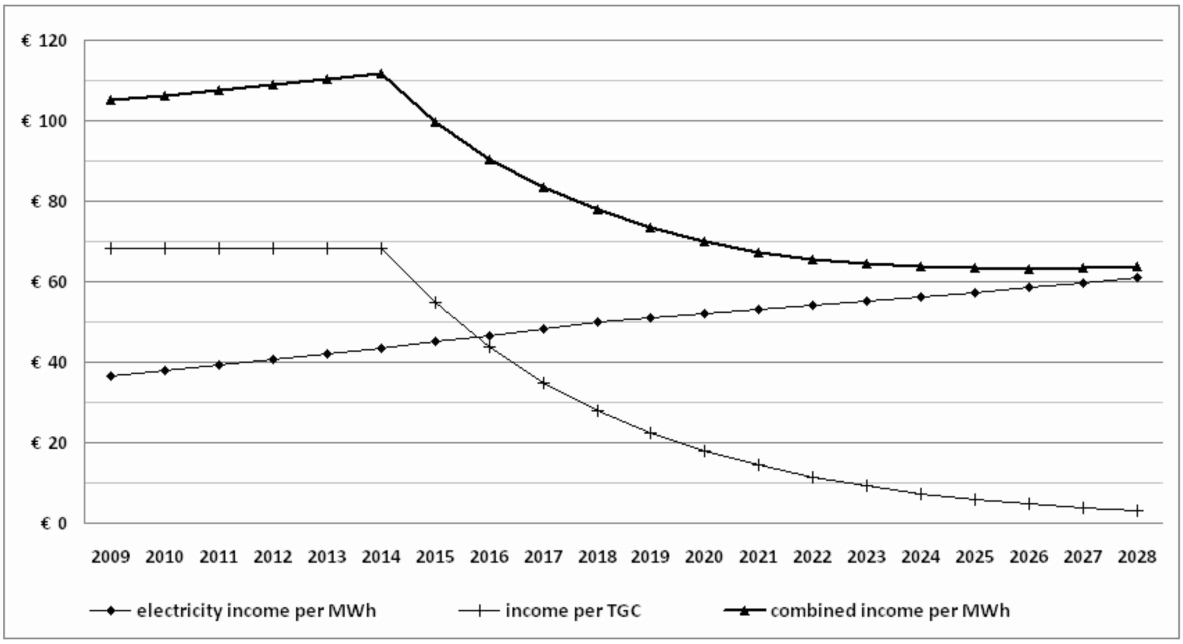

Figure 2: Illustration of price development in the base case.

70.1%, we calculate an IRR relevant for investors of 9.49% for a Polish 20-MW reference project (Table 3).

Table 3: Results market sale of TGC and electricity.

Income per TGC 2015–2028 (€)	**0**	22.78	34.17
Combined income (€)	**36.67**	59.45	70.84

[23] The annual 20% decrease is considered as a simple rule of thumb. A more sophisticated alternative determination of expected values of the degree of annual quota fulfillment, for example, as a basis for the considered TGC price development, would involve more assumptions and be less transparent.

Equity quota banking case (%)	**70.1**	38.8	23.2
Equity required (million €)	**21.8**	12.1	7.2
IRR banking case (%)	**0.51**	6.61	10.51
IRR base case (%)	**9.49**	12.27	15.70

3.3 Option 2: bilateral contracts

Bilateral contracts constitute an opportunity to avoid price variability, as RES power producer and retailer agree to trade electricity and certificates at fixed prices during the time of the contract. Because banks accept the incomes of the project as secured by the contract, a banking case is no longer necessary. As a consequence, the price agreed in the bilateral contract has a direct influence on the level of the equity ratio. The hypothetical bilateral contract for this project shall comprise agreed prices for electricity and TGC. The benchmark for the power-price component is the 2007 RES remuneration of €36.67 (PLN 128.8) set by the URE (2008b). To simplify we use a value of 130 PLN/MWh in the contract. TGC prices in contracts ranged between €42.71 (PLN 150) and €68.34 (PLN 240) in 2008 (POLPX 2008). With €55.52 (PLN 195) per TGC, the average of this range shall be used for the TGC component of the contract. This implies that the project has a combined income of €92.54 (PLN 325) per MWh of power generated and leads to annual project income of €4.9 million (PLN 17.1 million).

Table 4: Sensitivity analysis for bilateral contracts.

Combined income (€)	75.45	79.72	84.00	88.27	**92.54**	96.81	101.08
Combined income (PLN)	265	280	295	310	**325**	340	355
Equity ratio (%)	30.0	25.4	20.7	16.1	**11.4**	6.9	2.2
IRR (%)	5.10	6.78	8.70	11.02	**14.07**	18.64	29.25

Under consideration of the bilateral contract above, the project requires an equity ratio of 11.4% or €3.6 million (PLN 12.5 million) to fulfill the requirement of $DSCR > 1.3$. The IRR of option 2 is 14.07%. A sensitivity analysis shows how tightly IRR, equity ratio, and negotiated prices are linked (Table 4).

3.4 Comparison with financial-market investment

The two investor strategies considered above lead to positive IRR. For the values that we consider the most relevant (columns in bold in Tables 3 and 4), the IRR is higher in the case of a bilateral contract than in the market-trading option. Under the bilateral-contract option, the IRR strongly depends on the prices negotiated for electricity and TGC (Table 4). For example, if an investor faces a bad negotiating position and the IRR threatens to be under the IRR of option 1 of 9.49%, the investor should consider selling electricity and TGC on the free market. Even in the worst-case scenario considered in option 1 the IRR remains positive and the project is not in danger of illiquidity.

To evaluate the attractiveness of the reference project for an investor, it is necessary to account, in addition, for the opportunity of an alternative financial-market investment. For this comparison, typically the capital-asset-pricing model (CAPM) is used (Böttcher and Blattner 2006, Perridon and Steiner 2007). If the expected return of the CAPM exceeds the IRR of the real investment project, the project should be abandoned. We derive a CAPM reward-to-risk ratio for wind-farm projects in Poland of 9.84%.[24] This value exceeds the IRR of 9.49% calculated for option 1, meaning that trading TGC and power on the free market is not interesting under the Polish TGC scheme. Under option 2, the conclusion of a bilateral contract with a combined income of over €86.20 (PLN 303) is necessary (see also Table 4).

Our analysis shows the bilateral-contract option to be more profitable than direct reliance on TGC and electricity markets alone. As a consequence, TGC trading at the local certificate exchange would be expected to dry up, a tendency which can be seen (Subsect. 2.1).[25] This weakens the TGC market as the central element, suggesting the efficiency of such schemes. The high quota requirements in Poland are likely to imply persistently high TGC prices, making these prices *de facto* more predictable. This moves the scheme effectively close to one with feed-in tariffs, with guaranteed prices for green electricity.[26] At the same time, the high quotas enhance the uncertainty as to how the system will develop in the next decade. Given the favorable investment conditions found in this section, we conclude that in Poland indeed a relatively fast RES expansion pace

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[24] The figure is calculated as 5.7%+0.66·6.25%, where 5.7% is the risk-free rate of interest [corresponding to a similar state bond, *cf.*, *e.g.*, Comdirect (2010) for May 2008], 0.66 the beta coefficient (calculated based on the indications of a self-compiled wind power peer group), and 6.25% the risk premium (Damodaran 1999: 72).

[25] This is in line with Kildegaard's (2008) prediction that capital-intensive technologies with low operational costs – such as wind power – will typically find more profitable financing via contracts than by way of TGC exchange trading.

[26] Of course, feed-in tariff schemes do not implement a particular RES quota.

can be expected, mostly based on wind power.

4 Overcoming barriers to RES use as a justification

We study now how overcoming barriers for renewable-technology deployment supports the application of the Polish TGC scheme.[27] We wish to emphasize that there is no established methodology to assess such ancillary reasons for RES support policies. Closest to our analysis is OPTRES (2007: ch. 12), which focuses on administrative, grid, social, and financial barriers. Our categorization of barriers is more adapted to the situation in Poland as a new EU member state with little previous experience of RES. Because net social benefits of overcoming barriers are hard to quantify, the assessment is mostly qualitative. We consider six kinds of barriers. The first two, legal and institutional barriers, pertain, respectively, to the legal structures and efficient regulatory institutions to enable or facilitate integration of renewable generation capacity into power supply. Both are located within the legal system of an economy. Further preconditions for additional RES technology deployment include the available infrastructure, and the availability of funding and of the technologies in question. The sixth aspect is social acceptance of RES technologies. The barriers tend to lock in energy systems with the previously implemented technologies. Moreover, the barriers hamper the carbon-price signal (as generated by an ETS or an emissions tax) from becoming fully effective. Our discussion focuses mostly on wind power, as the most important RES in Poland in the near future (Sect. 2).

The importance of the *legal* framework and functional regulatory *institutions* for the economy in general and the integration of new technologies in the energy sector in particular is well established (*e.g.*, Golini 2005, OPTRES 2007, Williamson 2000). Given the state monopoly for power generation, transmission, and distribution in Poland until 1991, there was no quick rise of the supply of renewable electricity after the fall of the Iron Curtain (URE 2007a). How has the establishment of a TGC scheme been necessary, or helpful, for overcoming legal and institutional barriers?

The two major regulatory elements supporting RES use and the TGC scheme in Poland are the Energy Law Act and the energy regulatory office URE, both established in 1997 (ERRA 2009, Sejm 2010). The adoption of the Energy Law Act was the decisive step towards a liberalized and more decentralized national power generation system with unbundled generation, transmission, and distribution (Szwagrun 2004, URE 2007a).

[27] We are grateful to Paul Twomey for his input on this section.

The reforms of the Polish energy sector were especially made in view of the Polish EU accession, which implied compliance with the requirements of the internal EU electricity market and the EU expansion target for renewable electricity (Ministry of Economy and Labour 2005).[28] At the concrete administrative level, four kinds of permissions are currently necessary to establish a new RES plant (PAIiIZ 2009a,b, URE 2010b): an environmental approval from local authorities, the connection agreement with the local grid operator, the construction permission from local authorities, and the power supply license from the URE. The imprecise nature of the regulations to obtain these permissions has been described as the biggest barrier to wind-power expansion in Poland (PAIiIZ 2009a). As a result, project development (before construction) has been taking 1–5 years, so that the time to complete an investment project ranges between 4 and 7 years. As a consequence, EU legislation, not the national setup of the TGC scheme, has been decisive for overcoming legal and institutional barriers since Poland's democratic turn. The problem of imprecise rules to obtain permissions lies with the Polish legislator. To overcome this, the TGC scheme may, at best, be helpful due to additional applications, but it is not necessary.

Infrastructure problems are relevant in Poland in relation to grid access for decentralized suppliers, and plant construction (PAIiIZ 2009a). For wind-power plants, grid access is a typical issue, as their location does not necessarily fit well with the national grid (Paska *et al.* 2009, URE 2007a). Another issue is the local transport infrastructure (especially roads) to bring plants and necessary machinery to the construction sites (PAIiIZ 2008, 2009a). Improvement of transport infrastructure is often part of the licensing agreement with local authorities. To realize a project, investors may need to pay the additional costs of both grid connection and infrastructure improvement.[29] The TGC scheme clearly helps to finance the additional costs in relation to grid connection and infrastructure improvement. One may question, however, the extent to which these investments are among the tasks of a renewable-technology investor.

Investment *funding* constitutes another typical issue (*e.g.*, Kann 2009, OPTRES 2007). We discuss in addition the availability of the *technologies* themselves and of the knowledge necessary for their erection and operation. Funding barriers exist especially for potential domestic investors and operators, who often lack equity or sufficient credit

[28] The internal EU electricity market requires that decentralized generators are able to supply electricity from arbitrary sources (within the established safety bounds) to the national grids (EU 2003); the renewables expansion targets are described, in particular for the single member states, in EU (2001).

[29] With an average cost of €1.6 million per MW of wind power installed, PAIiIZ (2009a) estimates the grid connection costs for a project with €0.5–0.8 million, and the additional expenses related to auxiliary and road infrastructure (net of equipment transport) as about €0.5 million/MW.

from Polish banks (BSJP and Taylor Wessling 2009b, PAIiIZ 2009a). Attracted by the high expected rentability, major investors have been coming from abroad, including Germany, Portugal, Spain, and Switzerland. Part of the Polish situation is that, until recently, technology for commercial renewable electricity generation has not been nationally produced (Ministry of Economy and Labour 2005, PSEW 2010).[30] Technology availability constituted a significant barrier, with delivery delays for wind turbines of over 2 years (PAIiIZ 2009a). Due to the abandonment of orders outside of Poland, and, to some extent, also from Poland, the problem has practically faded away during the world financial crisis. The TGC scheme has certainly been helpful for these barriers not to block the development of RES technology deployment, and necessary for the relatively fast recent expansion pace. However, it is to be noted that most of the investment-related payments (apart, *e.g.*, from payments for grid connection and infrastructure improvement) have been received by foreign plant producers and project developers.[31]

A further set of possible barriers for the additional deployment of RES technologies pertains to *social acceptance*. Social barriers may become manifest, for example, in low specific demand for renewable electricity by consumers, or in opposition from local public or local authorities (OPTRES 2007). A particularity of the Polish electricity market is that the prices for domestic consumers are fully regulated by the energy regulatory office (URE 2009).[32] The fraction of renewable electricity provided is fixed under the TGC scheme and has still been relatively small. Hence, the possibilities for consumers both to reveal their preferences on the power market and to perceive the market development have remained limited.

5 Conclusions

The introduction of a quota obligation scheme to control the fraction of green electricity in national power consumption can be important for a country on the economic level and for its environmental and energy policies, especially if there is little previous experience of RES use for power generation. After all, a policy intervention should be beneficial for society. Poland, as a country in transition and a new EU member state, whose electricity generation was at the time of the introduction of the TGC scheme over 95% carbon-based and under 3% on RES, is a case in point.

[30] In 2009, a Danish turbine-blade manufacturer opened a first plant in Poland (PAIiIZ 2009a).
[31] The costs of the generator make up about 75–85% of the average cost of a usual wind-power investment (PAIiIZ 2009a).
[32] In 2008, the prices for industrial consumers and small and medium businesses were liberalized.

We study the Polish TGC scheme with regard to its economic functioning, and its justification on politically pragmatic grounds, *viz.* with reference to overcoming typical barriers for renewable-technology deployment. As set out in the Sect. 1, the RES target agreed upon as a part of its EU accession treaty has meant that the country should quadruple its green power fraction of total electricity generation within 5 years from the implementation of the scheme. The implementation of correspondingly ambitious annual RES quotas has been driving the developments under the scheme. The installation of RES technologies could not keep pace with the requirements for green-power generation according to the RES quotas. During the first year after implementation, TGC prices rose to their system-implied upper bound and have tracked it since (POLPX 2010b). We expect that the annual targets will not immediately be met in the next years, implying continued high TGC prices. At the same time, the uncertainty about the time when the national target will be met creates a considerable TGC-price uncertainty for the medium future. Not surprisingly, the option of a bilateral contract with a distributor that specifies TGC and power prices in advance proves more attractive for a new generator than market sale of certificates and green power. Nevertheless, investment incentives are high, especially for wind power. In this sense, the scheme is economically functional and effective regarding stimulation of expanded RES use for power generation.

Our findings with respect to its justification on politically pragmatic grounds are more mixed. With its high investment incentives, deployment barriers related to infrastructure, funding, and technology availability are alleviated. However, to overcome barriers for expanded RES use on the legal or institutional level, the scheme is not necessary. The impact on social acceptance of RES use may be negative when, after their liberalization, power prices for consumers start to rise.

Due to lack of data, at the moment it is not possible to investigate the wider economic impact of the scheme in Poland, for example, in terms of sizable effects on power prices, job markets, and stimulation of industry development. Such quantitative analysis of possible side-effects of the scheme would constitute an important complement to our consideration of overcoming barriers, but must be left for future research.[33] One notable side-effect from the environmental point of view is that the substitution of wind power for coal will tend to abate pollutants that are only insufficiently regulated otherwise and in particular not captured under the EU ETS or the protocols of the Convention on Long-range Transboundary Air Pollution, of which Poland is a signatory (*i.e.*, nitrogen

[33] Studies for countries with a longer implementation history of RES support policies, including the USA, tend to report critical results in these regards [*e.g.*, Schmalensee (2010) and the literature cited in footnote 4].

oxides, sulfur emissions, heavy metals; *cf.* UNECE 2010).

Our considerations in this paper make it clear that the main driver behind the developments in Poland have been provisions on EU level. This concerns especially the motivation to introduce a TGC scheme and the definition of quota levels. Hence, a comprehensive judgment of the TGC scheme in an EU member state in view of its justification also needs to take account of the relevant EU policies. (Obviously, this more comprehensive discussion is beyond the scope of the present paper.) Note, however, as one aspect of the general justification issue, that neither from this paper nor from the literature cited in the Sect. 1, a rationale arises as to how the RES quota should be specified.

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